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powder2power

Design of an Optimized Utility-Scale Heliostat Field Coupled with a Particle Fluidized Bed Solar Receiver

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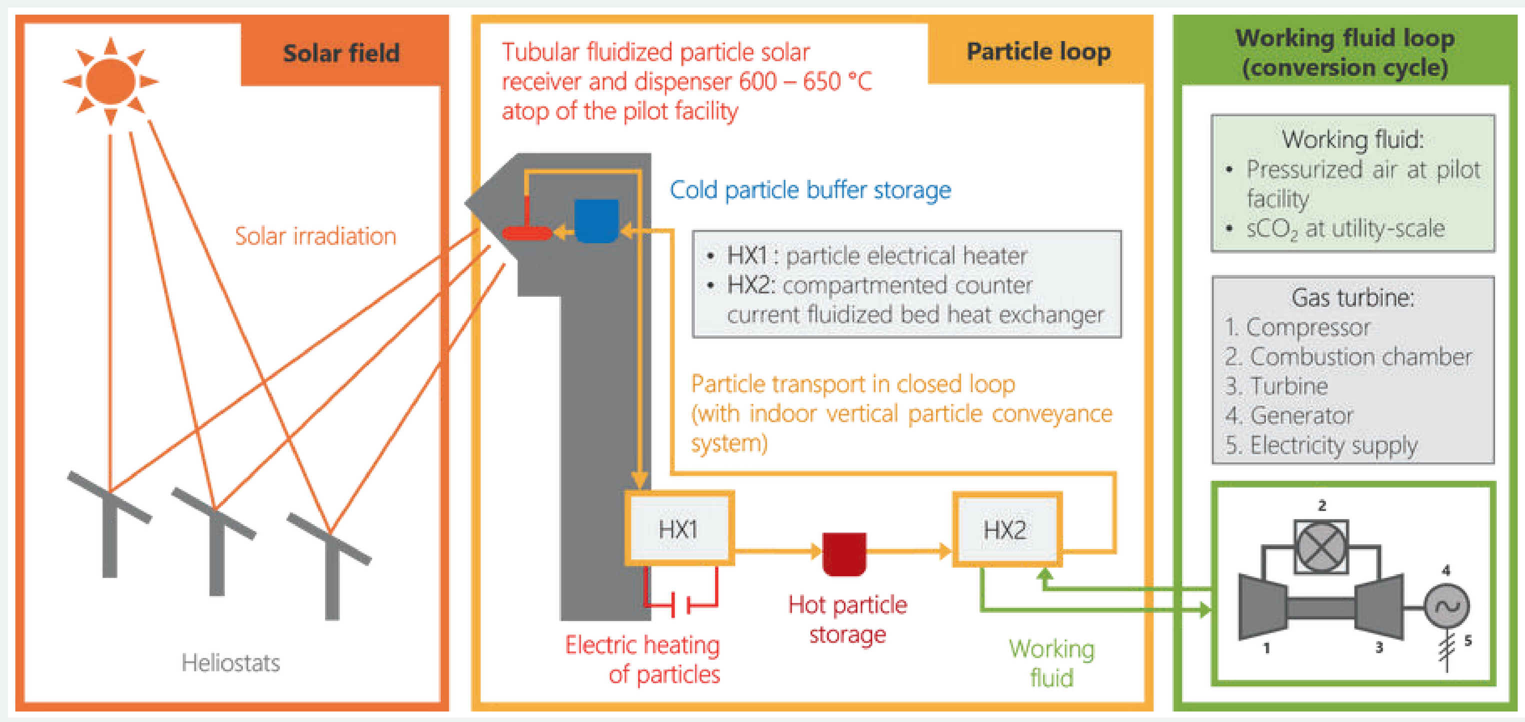
INTRODUCTION

The Powder2Power (P2P) project [1] aims to demonstrate at the MW-scale the operation of a fluidized bed solar receiver coupled with an electricity-driven particle superheater, a crossflow fluidized bed heat exchanger and a Brayton cycle gas turbine. This concept will be tested at the Themis tower facility (Targasonne, France).

Within the P2P project, one of the tasks aims to study the design of utility-scale power plants, in particular the heliostat field and the solar receiver. This paper describes the methodology developed to optimize the heliostat field layout, tower height and receiver geometry for a given thermal power. Results for a 50 MWth case are presented.



OPTIMIZATION METHODOLOGY

The challenge in this optimization is to maximize the photo-thermal efficiency (optical efficiency multiplied by thermal efficiency) by modifying the tower height and the aperture size.

To perform this task, an optimization tool was developed using *Matlab* where the heliostat field is created with *CoPylot* [2], simulated with the ray-tracing software *Solstice* [3], and where the solar receiver performance is calculated with a thermal model based on the Net-Radiation Method [4]. For a given thermal power absorbed by the particles, an optimal photo-thermal efficiency is achieved by modifying the tower height and the cavity aperture dimension with the design parameters (Sevilla, Solar Noon at Equinox, DNI = 900 W/m²). The tube wall temperature must be kept below 900°C.

RESULTS

The optimization was carried out for different thermal powers and 4 different particle inlet temperatures, from 400°C to 550°C. The objective particle outlet temperature was kept at 650°C. The graphs below present the results for a 50 MWth case.

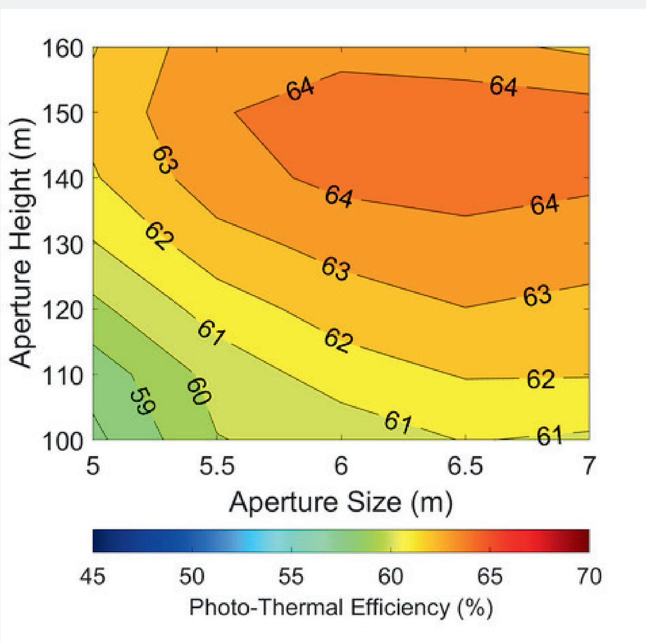
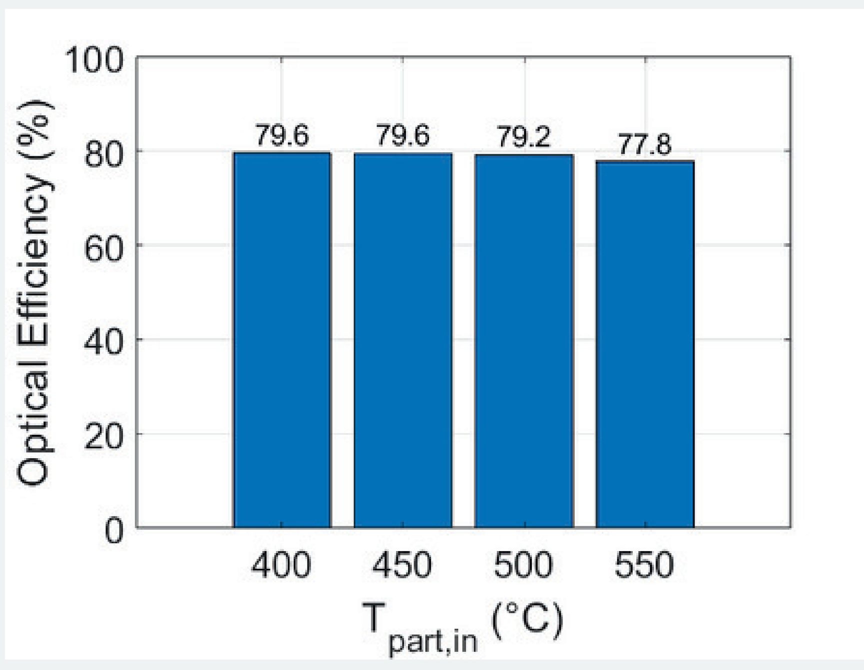
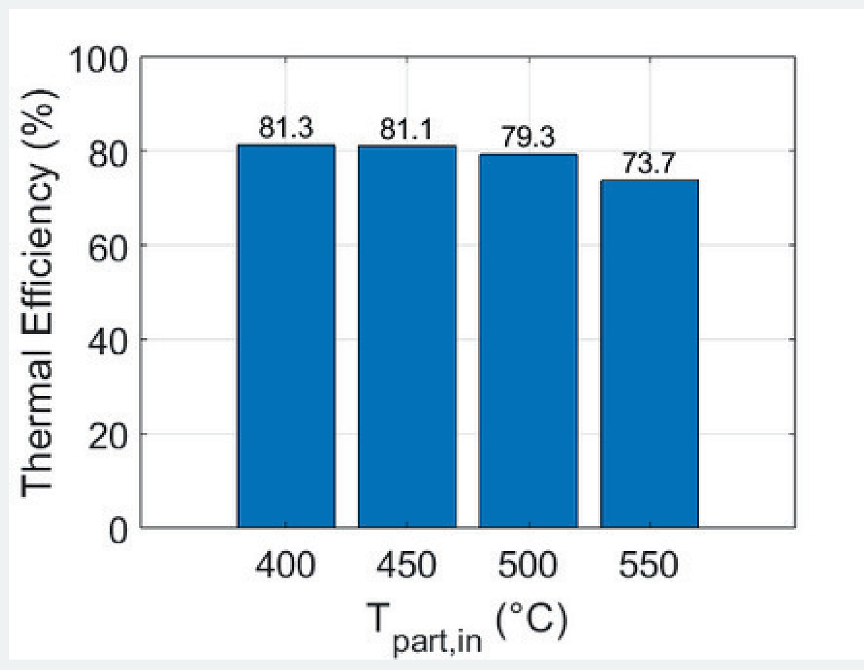


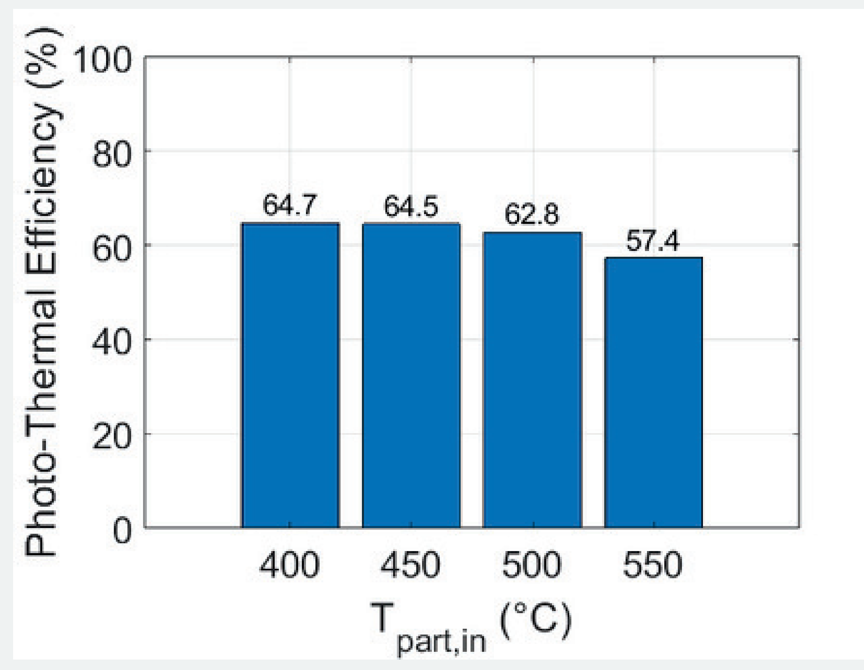
Photo-thermal efficiency profile for Tpart,in = 400°C



Evolution of the optical efficiency for increasing particle inlet temperature



Evolution of the thermal efficiency for increasing particle inlet temperature



Evolution of the photo-thermal efficiency for increasing particle inlet temperature

With the optimized receiver geometry and heliostat field layout, operational maps can be generated and consist in, on one hand, a map of optical efficiency depending on the sun position (azimuth and elevation), and on the other hand, a map of thermal efficiency depending on the power at the receiver aperture. To keep the particle outlet temperature at 650°C, the particle flowrate is decreased or increased.

REFERENCES

[1] https://powder2power-project.eu/

[2] L. T. Hamilton & al., “Demonstrating SolarPILOT’s Python API Through Heliostat Optimal Aimpoint Strategy Use Case”, Energy Sust., 6 pages, July 2021, doi: https://doi.org/10.1115/ES2021-60502

[3] https://www.meso-star.com/projects/solstice/solstice.html (03/17/2025)

[4] M. F. Modest, “Radiative Exchange Between Gray, Diffuse Surfaces” in Radiative Heat Transfer, 3rd edition. Oxford, UK, 2013, ch. 5, sec. 3, pp. 165-173.

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